Transcranial Magnetic Stimulation (TMS) Neurofeedback – A Multimodal, Multiphase Approach to Stroke Rehabilitation using EEG-BCI

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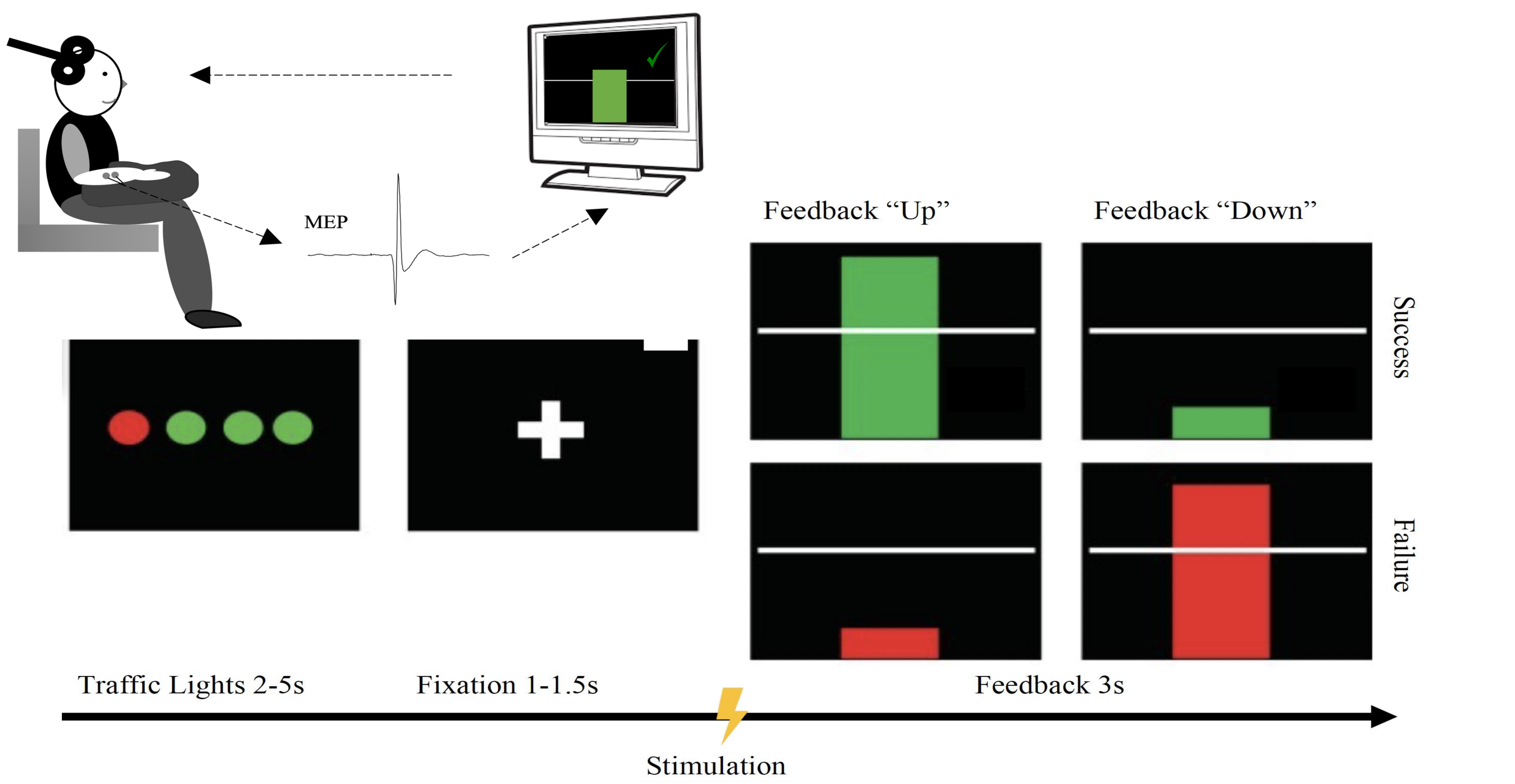
Introduction

Motor imagery and neurofeedback

- Motor Imagery (MI) based Brain Computer Interfaces (BCI) can facilitate very early motor rehabilitation during the acute post-stroke period characterised by high levels of impairment and paradoxically increased plasticity.
- Current EEG-BCIs require substantial time to learn to use.
- We suggest a multimodal and multiphase approach that may allow stroke survivors to learn to use the BCI more rapidly, enabling early bedside intervention.
- **H - TMS Neurofeedback prior to EEG-based BCI will facilitate faster and more accurate control of the BCI**

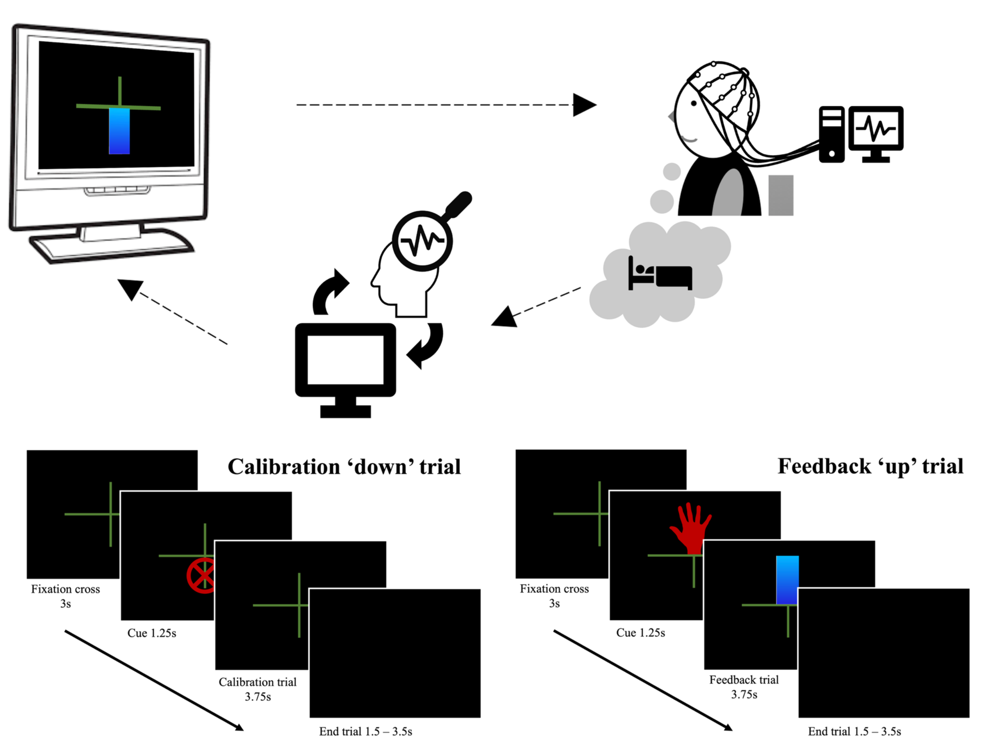
Methods

Experimental paradigm – TMS Neurofeedback



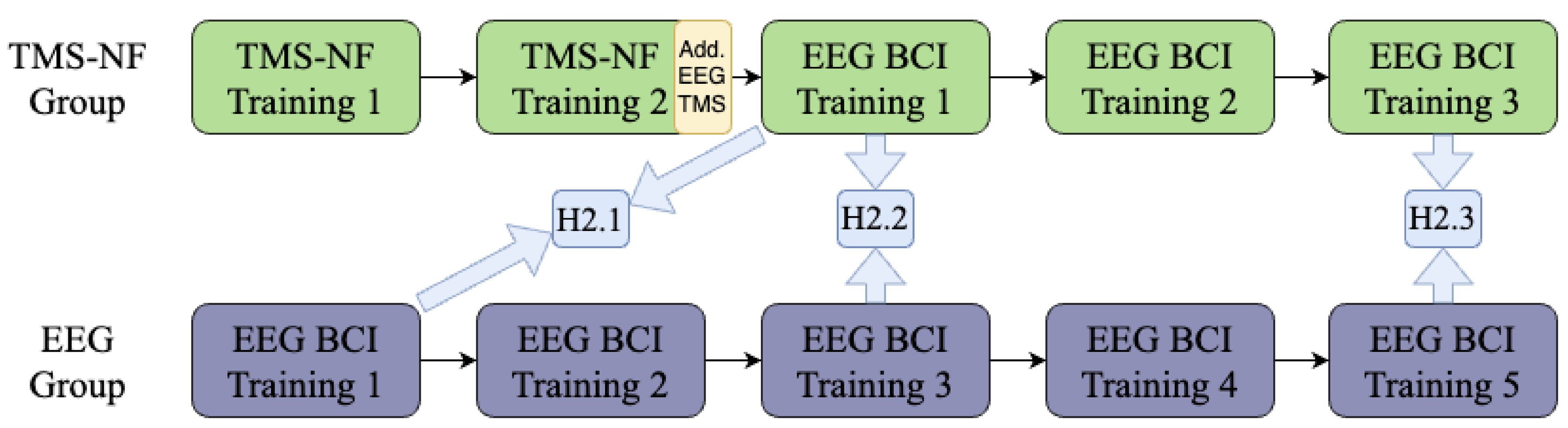
- Participants perform MI in one of two states – during the 'Up' state they imagine forceful movements of fingers, during 'Down' they imagine the hand and fingers cold, dead and detached
- TMS pulse is triggered while participants perform MI. Motor Evoked Potential (MEP) amplitude is displayed as feedback to the participant[1].
- TMS-NF Protocol – 1) traffic lights (red if EMG is above threshold), 2) fixation, and then 3) feedback.

Experimental paradigm - EEG BCI



- Graz style BCI in OpenViBE software – using a common spatial pattern (CSP) filter combined with Linear Discriminant Analysis (LDA)[2].
- Each session started with a feedback-free calibration block to train the BCI.
- Certainty of BCI in classifying 'Up' and 'Down' states displayed to participant.[3]

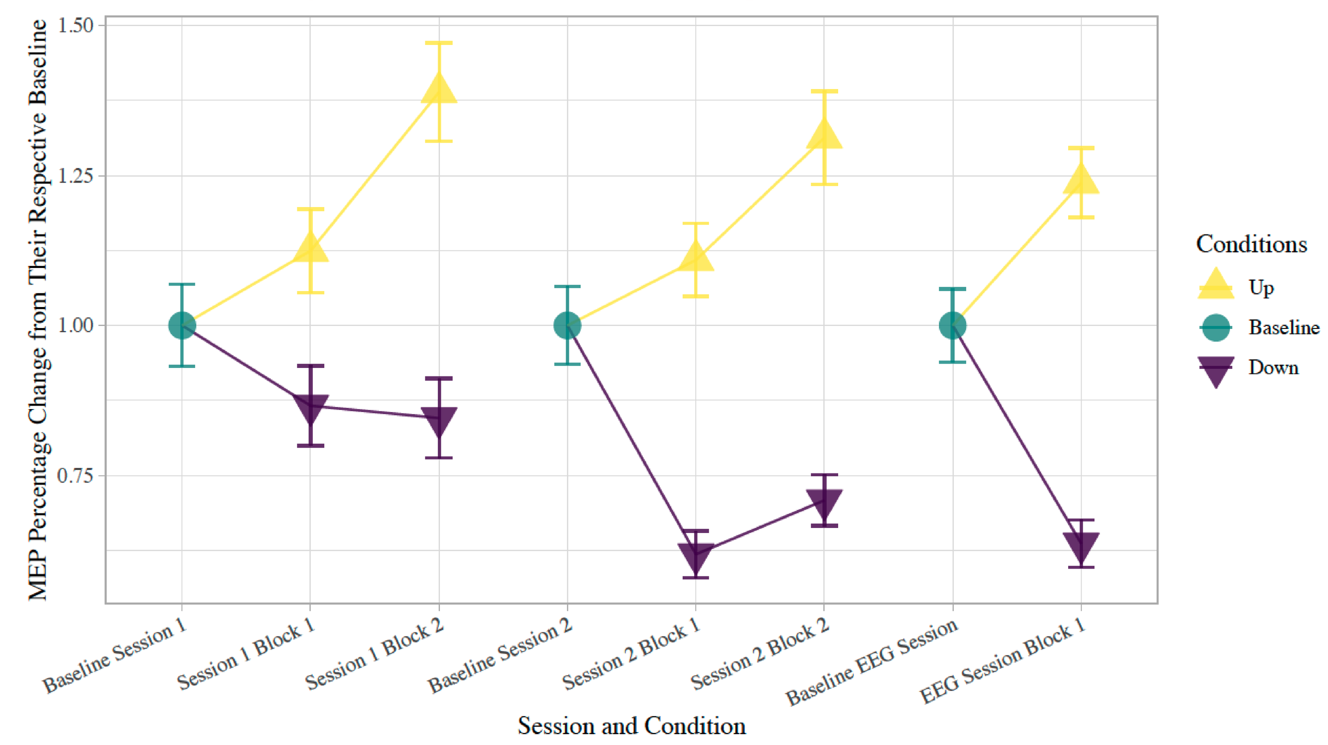
Experimental design



- N = 17 in each group, same MI instructions for both groups
- Training – 5 blocks of 30 (15 Up/Down), randomised.

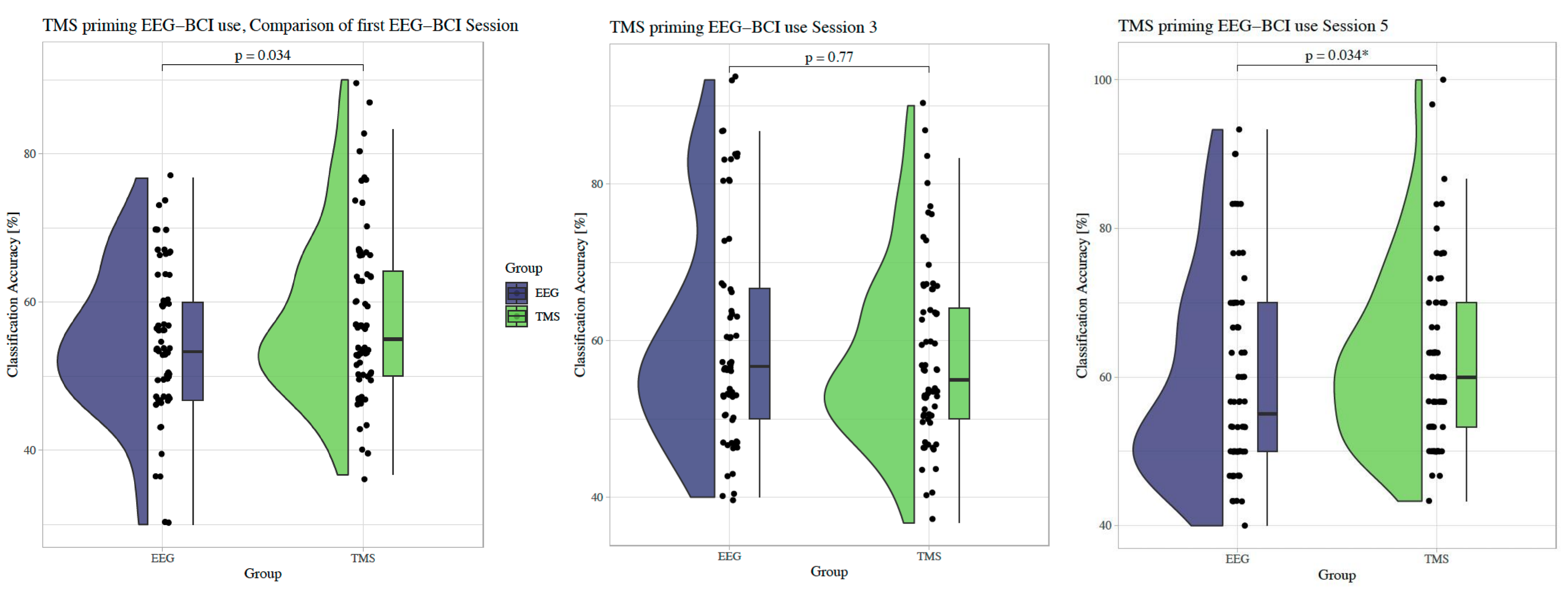
Results

TMS-NF – Change in MEPs in Up and Down conditions



- Training with MI instructions systematically impacted MEP amplitudes over time - participants were able to regulate their MEP amplitudes using MI early on, without needing much training.
- MEP amplitude changes not associated with background muscle activity.

Classification Accuracy of BCI at three comparison points



- Graphs display distribution of Classification Accuracies (CAs) of the EEG group and the TMS-NF group at the three comparison points for Hypothesis 2.1, 2.2 and 2.3.
- At the start of EEG BCI training session 1 for both groups, the TMS-NF group had higher CAs (H2.1)
- However, the TMS-NF group did not have higher CAs at the start of their first EEG BCI session than the EEG group at the start of their third session (H2.2)
- After 3 sessions of EEG BCI, the TMS-NF group had higher CAs than the EEG group had with 5 sessions (H2.3).
- The TMS-NF group were able to learn to use the BCI faster and with better performance than the EEG only group.

Discussion

- Priming using two days of TMS-NF may assist EEG-BCI users to develop robust mental imagery strategies that transfer well to an EEG BCI, enabling better control within a shorter timeframe. Given that EEG BCI is more portable and cost effective, this may enable a two-phase approach where TMS-NF is used at the bedside in the early days after stroke followed by self-directed EEG BCI rehabilitation at home using wireless, wearable technology.

References

1. Ruddy, K., Balsters, J., ... & Wenderoth, N. (2018). Neural activity related to volitional regulation of cortical excitability. *Elife*, *7*, e40843.
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3. Simon, C., & Ruddy, K. L. (2022). A wireless, wearable Brain-Computer Interface for neurorehabilitation at home; A feasibility study. *IEEE*.